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ABSTRACT

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Scientific Literacy:
Interpretations of a Cross-Section of Our Society

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Abstract

In order to purport a model of how scientific literacy is recognized against or in a backdrop that may include its purposes and goals, we need the perspectives and voices of individuals who are stakeholders in the science education reform process. The purpose of this study is to examine the interpretations of scientific literacy from a cross section of the American society who occupy positions of responsibility that relate to science and scientific literacy. The stakeholders in this research effort include participants selected from a sample of scientists, science educators, teachers, administrators, community persons influencing educational decisions, and parents. This qualitative research study includes an analysis of nine open-ended, in-depth interviews. The results (findings) of this study will show the emergence of themes or categories that relate to how our participants recognize (define and measure) scientific literacy.

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Scientific Literacy:

Interpretations of a Cross-Section of Our Society

Scientific literacy emerged as a label to describe a primary goal of science education in the 1950's. Paul Dehart Hurd is generally credited with identifying this label in an article from 1958 (Hurd, 1958). As is evident from research for other papers in this set, other science educators had also provided a description of scientific literacy quite consistent with Hurd's definition from the mid 1800's. In the more than 40 years which have passed since Hurd's coining of the phrase, scientific literacy has come to mean a set of knowledge and/or skills which are essential to function in a literate fashion in our society.

Our research has focused on how citizens from a cross section of American society, who are occupied in positions which have a science related function, believe that scientific literacy can be recognized and developed in individuals. The primary rationale for this research is to examine how various individual stakeholders in the science education reform process view the goals, purposes, and meanings of scientific literacy. To this end, the project has examined what scientific literacy means to participants, how the participants view their roles in facilitating the development of scientific literacy, factors which the participants see as constraining or promoting the development of scientific literacy, and how the participants believe scientific literacy can be measured or evaluated in others.

The purpose of this research study is to discern commonalities (and differences) of views about the goal of scientific literacy. In this paper, primary emphasis is placed on the issue of recognition of scientific literacy. To that end, the overarching research question is stated as: What characteristics of humans are believed to be the indicators of scientific literacy as judged by science education stakeholders?

In the following sections, the research methodology, results, and discussion will be presented. Subsequent reports of this research will expand on the topic to include factors which are identified as related to the development of scientific literacy.

Methodology

As a first step in the research, a questionnaire was developed through a systematic process which would serve as a means to determine the factors which participants believe would allow for

recognition of scientific literacy in themselves and others. See Figure I in Appendix A for a listing of the questionnaire.

Participants

Our participants were purposefully selected to include people with roles in promoting literacy, scientific literacy, and science. We developed a "potential participant matrix"' which included the categories of K-12 educators, administrators, community persons influencing educational decisions, informal science education centers, notable scientists, and others. Within these general groups, participants were selected by individual researchers on the basis of opportunity and convenience. Our participants currently include two Nobel laureate scientists, one university scientist/science educator, a principal, an elementary school teacher, a park administrator, two high school science teachers, and one parent. Participants were selected from a major university in Georgia and another in Texas, several schools in Georgia and one each in Nevada and Texas, and from other institutions in Georgia.

Each participant was interviewed individually at his or her convenience by a single researcher in the Fall of 1997. Each researcher used the semi-structured interview protocol shown in Appendix A. In addition to the interview questions, some demographic information was asked of the participants. Finally, each participant was asked to locate themselves with respect to two diagrams to see how they describe their role in the science/literacy spectrum. Interviews were audio taped and transcribed verbatim.

Participation in the study was voluntary, and participants were given the right to withdraw from the study at any time. The identity of a participant will not be revealed, unless the individual wishes for their real name to be used. Otherwise, a pseudonym is assigned to each person who will be in this paper as to their occupation or position.

Data Analysis and Framing

The transcribed conversations were reduced and interpreted in a search for patterns, categories, and themes suggested by the data. Data analysis, or framing, was conducted as an activity simultaneously with data collection, data interpretation, and narrative report writing. After the initial interviews, the research team met to "code" one transcript and to get a general sense of the data. Then each researcher individually read each transcript and one question in depth. Each researcher brought their preliminary analysis back to the larger group for discussion. This paper describes what we have learned in our preliminary analysis of the data. We discuss what we have learned with respect to the research questions initially guiding the study.

Findings

In positing or setting the stage for the recognition of scientific literacy the first element that is required is that of definition--what is the essential nature, as our participants understood

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'it,

of this concept? We ascertained participants' conceptions of scientific literacy in three ways: (a) We asked each directly to define scientific literacy. (b) We asked each to describe a scientifically literate person. (c) We asked each participant about their own scientific literacy. And (d) We asked how one can measure, know or recognize if a person is scientifically literate. For some, scientific literacy is associated with understanding sciences, particular objects, places of practice, language, bodies of knowledge, and the ability to make decisions informed by science. In qualifying themselves as scientifically literate, participants referred to traits and experiences such as: (a) science courses taken at the high school and/or college level; (b) interests or self-initiates that guided learning and explorations; (c) ability to find answers to their own questions; and (d) the extent that they can be informative to others. The four groups or categories of recognizing scientific literacy (indicators) that emerged in this study are: knowledge and skills; science as a way of thinking; disposition of interest; and experiences and activities. The emerging groups or categories of measurement of scientific literacy are: knowledge, skills, self-evaluation, evaluation of others, and degrees of scientific literacy.

Indicators of Scientific Literacy

Scientific literacy as knowledge and skills. The key concepts for the parent in the recognition of scientific literacy are knowledge and skills. Parents want their children to have knowledge of specific sciences, as well as science in general. But for a parent, knowledge of science is only part of what a scientifically literate person possesses. For one parent, a scientifically literate person must be knowledgeable to the extent that he/she is able to grasp the meaning of scientific terminologies or the meaning of knowledge in general. Knowing is not enough, one must be able to understand and generate meanings. The parent says, "[Scientific literacy reminds me of] Working in a lab. Understanding scientific terms like biology, general science, business science or just the general knowledge of things." Skills, in this parent's view, involve the ability to implement specific tasks of a scientists such as working in the lab. The scientist, like the parent, also posits that the essential nature of a scientifically literate person is knowledge but the scope and depth of this knowledge is different. A Nobel Laureate who perceives scientific literacy as being able to delineate the outer boundaries or limits of different sciences says, "a general familiarity with . . . the outline of the sciences, their relationships to each other, most important facts that we know about nature. The extent of the knowledge for the scientist is more rigid and specific than that of the parent. For the scientist, scientific knowledge is not only being able to determine distinctive differences among specific disciplines of science, but also involves being able to conclusively determine how different scientific disciplines may be

related.

Science as a way of thinking. A scientifically literate (knowledgeable) person can also be distinguished because this knowledge empowers or enhances a way of thinking that impends or affects decision making skills. As one secondary science teacher put it:

[Scientific literacy] means the ability to digest any amount of information . . . in an logical, rational manner and to come up with either an objective or subjective decision or opinion based on the facts presented. And, that can be in various forms whether it be in a video mode, a reading mode, whether the information is given to me as a graph, through various professional papers that might be presented and/or themes, through experiments or perhaps videos or movies.

The science teacher is concerned with knowledge of the sciences that places emphasis on cognitive abilities (ways of thinking). Scientifically literate students are able to empirically classify, decipher, and internalize scientific information from any source. This process involves critical thinking skills that are congruent to decision making skills. This teachers appears to be operating out of the same paradigm as the principal in that a scientifically literate person is able to make decisions. The principal says:

[Scientific literacy is] being able to make decisions, descriptions, take actions that are based on an understanding commensurate with that of an orthodox scientific [perspective] . . . They can put forth a cogent, logical argument that is at least believed by others.

The principal appears to be stipulating that the decision making of a scientifically literate person is an active process in which one is able to act on decisions and communicate rational postures or perspectives. The implication is there is a medium at work which has a critical role in convincingly putting forth one's argument.

Science as a disposition of interest. Some of the participants associate scientific literacy with a disposition, and in this case, a disposition of 'interest'. This disposition of interest can be termed as an inclination, mental state or self-consciousness (scientifically literate) that may be conditioned (as well as include) by knowledge and by ways of thinking. A Nobel laureate said:

For me scientific literacy is a consequence from interest . . . I would emphasize [the] active element . . . [It involves having an] interest in the outside world. The interest in human condition more than artifacts.

The consequences of having this knowledge or information about human conditions or the world spurs the active pursuit of solutions to better human conditions. This probably can be contrasted with the engineered tangibles of scientists such as technology and the generation of scientific

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information and theories.

Science experiences and activities. Several participants stipulate that in addition to interest in science, to be scientifically literate one must have experiences with science, either in school or in some other aspect of one's life. For example, one high school science teacher says, "I think I'm scientifically literate because as a science teacher I have to continue taking content courses in science in the master's and my doctoral program." She also describes her husband as being scientifically literate because his "degree is in biology, [though] at the present time, his job doesn't involve biology ... And yet he is always, because he is interested in [it], he is always keep[ing] up with it. And he does a lot of reading in scientific magazines and journals ... just because he is interested in it." Similarly, the chemist/science educator considers himself to be scientifically literate because, in his words, "I have a degree in science, several degrees in science, and because I teach science."

However, scientific literacy is not limited to those holding degrees in science. The parent also considers herself scientifically literate "in a general sense" because she has "had all of the basic courses that one needs to graduate from high school like chemistry, biology, and physical science." In addition, she possesses "a working knowledge of nutrition and general health situations" and she is "comfortable with Celsius or Fahrenheit, and the kinds of things you can use in everyday life." The chemist/science educator also says, "scientific literacy is accessible to a much wider range of people than those who major in science," but expressed the view that nonscientists must first be interested and motivated to acquire scientific literacy, either in school or afterwards. The Nobel laureate posits a similar view, and expresses that the concept of scientifically literacy includes

> people who are not scientists, ...ones who understand the world around them. For example, ones who understand how a television works, how an airplane can fly. They may have some idea about biological evolution--how humans evolved. So I think that scientific literacy is interest in the outside world--and also to some extent the inside world. Of course, you may be interested in neurobiology, in the ways the mind works. So I would think in general, scientific literacy is, in my opinion, associated with curiosity about the outside world in which we are living and, to some extent, also interest in the position of men in nature.

Thus, scientifically literate people are recognized by their interests, and by what they have experienced in school, on the job, or in life. In addition, one must consider what they actually do (or don't do). For example, the chemist/science educator communicates that a scientifically literate person would take "advantage of opportunities like ... visiting science museums,"

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whereas a scientifically illiterate adult "never reads any articles in the newspaper or magazines, or listens to television science programs."

Measurement of Scientific Literacy

The second element involved in the recognition of scientific literacy is measurement. The question here not only involves limits, boundaries, amount or degree, but must also obliges instruments with which to measure. The responses to this question can be divided into two groups. Some participants emphasized "how to measure" which relates to the utility of instruments. Other participants emphasized "how to know or recognize" which relates to the boundaries or limits of a scientifically literate person. The focus will not be on measurement, per se, but will encompass how participants would measure knowledge, skills, ways of thinking, and dispositions.

Measurement of knowledge. All of the participants consider scientific knowledge and understanding as a necessary factory for determining scientific literacy. Several participants suggested that scientific literacy can be measured by some sort of questionnaire or test (instrument), but they cautioned that there might be problems related with standards to measure (knowledge) scientific literacy. For example, a secondary teachers declares:

Obviously there is certain testing or criteria that can be met. But . . who sets those standards? . . . If we were to come up with something, a level, it would have to be overseen by independent judging criteria that would establish those facts.

In addition to testing, a scientist/science educator suggested interviews might be a way to measure scientific literacy. However he suggested one should

try to get the person to rank themselves on the basis of different questions you might ask. You might ask them some questions that don't ask them specifically for the answers, but ask them if you feel like you understand these items. On a score of 1 to 5, you might let the person judge themselves based on something like that. [scientist]

The secondary teacher is proposing that one can measure knowledge (scientific literacy) objectively using objective instruments or tests. The issue for this teacher, however, seems to be that of standards. Standards would have established levels of competencies to ensure reliability. The validity of these tests or instruments would be determined by the extent of the independent benchmarks. The scientist also believes that scientific knowledge can be appraised. The instrument of mechanism or measurement the scientist would utilize, however, would require some sort of subjective ranking of their understanding of specific scientific information. The knowledge (scientific literacy) or information one has learned can also be assessed or evaluated. Some of the participants indicate that this characteristic can be assessed or evaluated by what one thinks an educated or intelligent person should know but does not know. For

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example, a scientist says

I've met people that are surprised to learn that the stars are like our own sun. So even very . . . intelligent and educated people can be amazingly illiterate scientifically. And it isn't always possible to tell in advance.

For this scientist, it would appear that one can not always take for granted that an educated person is more knowledgeable about scientific information that lesser educated, nonscientists may take for granted as "universal."

Several participants further emphasized the relative and subjective nature of scientific literacy (knowledge). A scientist suggest, "There is not a single scale. There are multiple scales. And I think we have to take into account this multiplicity of scales before we can answer ... whether somebody is scientifically literate." According to a principal, measuring scientific literacy should be relative to what the surrounding group knows, and there is no absolute scale one can use. He states

It's inherent really that one can only gauge someone else's scientific literacy based on what one knows one's self -- or what one believes about one's self. Put me in a room full of biologists, and I'll come out being very nonliterate and somewhat uneducated. Take me and put me in a room of physicists and I come out on par. And put me in a room full of educators and I come out extremely scientifically literate.

The evaluation of one's knowledge (scientific literacy) here is posited as relative depending what one knows or is able to articulate as he or she communicates with literate verses nonliterate peers or colleagues. The relativity on one's knowledge is also contingent on one's paradigmatic framework. For the principal, teachers and scientists operate within different scientific paradigms.

Measurement of skills. The "how to know or recognize" persons emphasize the applicability of science information or skills to jobs or one's everyday life (limits or degree of the concept). These participants suggest one can know or recognize scientific literacy (skills) through self-reflection, personal observation and conversations:

I think just feeling comfortable with it [science] --with reading a newspaper and understanding the articles in there about scientific breakthroughs ... --not necessarily in detail . . . but you can read the article with some confidence and know what they are talking about. Or, feeling comfortable choosing a diet for your family and knowing why you are doing that. Or, having some degree of confidence in your physician when he prescribes something for you, you know what it is going to do to you body or not do.

[Parent]

I have several friends ... [whose] occupations are connected to computers and

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science. ... I have [a brother] who is a chemist and works with water testing. [I know] he's scientifically literate] because he can answer all the questions that I ask. I think a lot just in the every day conversations I can tell. And I do have friends where we talk about birds, we talk about trees. [Elementary teacher]

The parent's view is that skills are perceived as the ability to utilize one's knowledge effectively in the execution of cognitive tasks that may relate to critical analyzation of information.

Skills also involve the conscious, informed consumption (self-confidence) of the products of science, services of scientists, as well as scientific research and technology. Comparatively, the elementary teacher would appraise skills (scientific literacy) by one's ability to articulate the extent of his or her knowledge during an inquiry or in ordinary conversation. To this elementary teacher, skills are more than having an scientific occupation or being a scientific professional. Skills also involve how and to what extent one is able to communicate facts about entities that are studied by scientists such as naturalists or botanists.

While the variety of responses to this question regarding recognition of scientific literacy (knowledge, skills, ways of thinking, disposition of interests, and experiences in science) may be related to the wording of the question itself, responses may also be the result of the participants' differing definitions for the concept of scientific literacy. This is a question which deserves further analysis.

Self-Evaluation (measurement) of scientific literacy. One aspect of recognition, in terms of measurement, relates to how the participants perceived themselves as being scientifically literate. In qualifying themselves as scientifically literate, participants talked about their experiences, educational training, and their abilities to explore answers to their questions, as well and how well they are able to communicate information. These self-described characteristics also encompass the categories of knowledge, skills, ways of thinking, dispositions of interest, and experiences in science. Several participant's further indicate they perceive a relative dimension to self-evaluating the status of their scientific literacy. One teacher indicates that he is aware that his scientific literacy is declining relative to what scientists know is his field of science. In spite of this awareness, this teacher is still confident that the general public would perceive him as being scientifically literate. Others highlight that evaluation of their personal scientific literacy (knowledge, skills, ways of thinking, disposition of interest, and experiences in science) is relative to their social relative to their social surroundings, job status or scientific training. The zoo park administrator says, "A person's status of scientific literacy is relative to whether one works as a

trained scientist or not." The parent, takes a different perspective as to the relativity of scientific

literacy, although she does intimate that working in the field of science is important. The parent says

"Scientific literacy is relative to the extent you can see science in everyday situations around you. Science to me is [just] relative. Although I can't call myself a scientist or say that I am an expert at it in my field"

These participants' perceptions of how they would appraise their personal knowledge, skills, way of thinking and disposition do not involve any precise standards that can be assessed objectively. This measurement or self-evaluation process of one's scientific literacy is relative (period) for the parent.. This relativity takes on nonrestrictive characteristics or elements of comparing the extent of one's training. For the parent however, scientific literacy is also relative but only to the extent that one can or can not discern the science in the world of everyday things in one's environment.

A Scientist's views (self- evaluation) of his scientifically literate are in terms of what his knowledge, skills, ways of thinking, and disposition of interest allow him to do. These are his perceived abilities and are also relative to other people that surround him. He states

One's sense of scientific literacy is relative to the level of scientific literacy perceived by those around you. That is, you know more than they do, thus you can provide them with knowledge.

As indicated by the above statement, this scientist perceives that his scientific literacy is based on personal knowledge and skills that empower. This empowerment is relative in that he knows more science and thus "knowing more science" allows him to impart knowledge or teach science to persons who know less science.

Evaluation (measurement) of the scientific literacy of others. The participants in this study perceive that the evaluation of the scientific literacy of others would encompass characteristics that would be observed in themselves, but takes on more of the category of disposition of interest. Most of the interviewees (6 out of 9) referred to people who have some knowledge about or interest in knowing science. Such knowledge and interest can be either a consequence of school education or just learned through hobbies. On the other hand, a few participants believe that college degrees in science or formal training in doing science is the best indicator of persons who are scientifically literate.

For some, scientifically literate persons are those who read about science, are interested in science relevant information, have hobbies related to science, such as fishing, birding, and going to natural museums. Additionally, persons who use science in daily life (consciously or not) can

also be counted as scientifically literate. For example, one scientist/science educator says

Someone who is scientifically literate would ... [take] advantage of opportunities like ... visiting science museums, ... [ask] questions about some scientific situation or some environmental problem, and show some knowledge and some curiosity about science.

A secondary science teacher describes a person she considers as scientifically literate as doing

a lot of reading in scientific magazines and journals ... just because he Is interested in it. He is interested particularly in ... reptiles and avians, ... and he has even done some research on his own on certain snakes because he is interested in it. That's not his job, not his vocational knowledge, just something he .. [is] interested in.

The science educator measures or evaluates the scientific literacy of others by their actions--how and if they inquire about the musings of science or inquire about some global concern, as well as their disposition about science itself as a discipline or as a practice. However, the science teacher describes a scientifically literate person as an action oriented individual that keeps up with current scientific endeavors. The category that seems to be most important in determining whether other persons are scientifically literate is the disposition of interest.

On the other hand, three of the participants saw scientific literacy as coming from a degree in science. In this view, only a formal training can enable a person to have the background knowledge and thinking skills to possess scientific literacy. One scientist says, "I'm scientifically literate because I've been working as a scientist for all my working life." One secondary science teacher describes herself as someone who is scientifically literate because [she] "had a tremendous amount of training in the biological scientific areas." This view that people who are educated or trained or as scientists are also scientifically literate presupposes the assumption that a well trained scientist is, as a result of his educational experiences, a scientifically literate person. This perception contrasts with an earlier quote which indicated that education (training or experience in sciences) does not necessarily mean that the person is scientifically literate.

Although the perspectives about how to define a person as a scientifically literate or illiterate are different between the two groups, both groups see scientific literacy as a complex, dynamic function of science topics, experience in science, context, and other factors. One cannot simply say a person is scientifically literate or illiterate in general, but can only refer to their degree of scientifically literacy in a particular area (e.g., biology, chemistry, physics, etc.) and specific cultural context (e.g., in public or in a university setting). This dynamic nature is a very important idea to take into consideration when studying scientific literacy.

Degrees of scientific literacy. One other thing that became clearer through indirect

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questioning is that the participants do not consider scientific literacy to be an all or nothing affair--

i.e., one either has it or not. Rather, some participants describe scientific literacy as if it were a

continuum. The chemist/science educator, for example, mentions, "degrees of scientific literacy." One high school science teacher describes scientific literacy in terms of "levels" and states, "I don't think we should be so worried about the exact level, you know, what's the cut-off point of scientific literacy. If you are above this point you're literate, or you are below this point you are not." She also expresses that one's scientific literacy is related to an innate ability to learn or do

science, which in turn is often dependent upon cognitive development: "what do we call scientifically literate in an elementary child would be one thing, and what do we call scientifically literate at high school level would be different, or the college level, or at the graduate level."

One of the reasons there are "degrees" or "levels" of scientific literacy is because of the great breadth of the sciences today. Participants agree that one does not have to possess, indeed cannot possibly acquire, full knowledge of all the various scientific disciplines to be considered scientifically literate. For example, the elementary teacher remarks, "I think you can be literate in part, in one scientific area, but not in all others. ... I think if a person has anything science related that is a part of their everyday lives, that is some form of scientific literacy." Some participants affirm that what one needs to be considered scientifically literate is a sufficient store

of knowledge and understandings, along with certain skills, so that one can learn more science when necessary. One high school science teacher puts it like this: "Although I'm not scientifically knowledgeable in every area of science, I think I know how to go back getting information that I would need to know about an area even if [I] don't already know about an area. So, I think I know the methods of getting scientific knowledge if I need it."

An analysis of the above statements reveals that irrespective of how each participant perceives scientific literacy, scientific information or knowledge is paramount. The question now becomes: What scientific information specifically (science experiences) are most conducive to effectuate adequate scientific knowledge, scientific skills, science as a way of thinking, and science

as a disposition of interest for the key stakeholders in science education. The answer or answers are contingent upon how each stakeholder recognizes and measures scientific literacy in the context of its value in our society.

Discussion

Rodger Bybee has declared that scientific literacy is "the fundamental goal of science education" (Bybee, 1997, p. 46). He says, "a statement such as 'achieving scientific literacy for

all learners' expresses a general purpose that is persuasive and even patriotic. Who could be against such a goal?" (1997, p. 46). Indeed, none of the participants in our study questioned the need for personal or societal scientific literacy. In other words, they all agreed in principle that the goal of scientific literacy is a worthwhile pursuit. However, no two people in our study offered the same definition or description of scientific literacy. That is not to say that they disagreed with one another; they were simply unaware of any other person's responses to our questions. None of them discussed someone else's conception of scientific literacy to which they objected. Thus, the concept of scientific literacy seems to be broad enough to encompass a variety of views. Accordingly, we believe the participants' characterizations of scientific literacy usually differed in emphasis rather than having incompatible natures. For example, one person might emphasize scientific knowledge, while another would stress the ability to think scientifically. Both of these views describe aspects of scientific literacy, and do not represent true disagreement about the concept. We are therefore proposing a conceptual framework that combines the essential characteristics of scientific literacy as discussed by our participants (Figure 1 in Appendix B). This framework is a slight modification of the one proposed by Champagne and Lovitts (1989), and involves three broad categories: experiences for developing and maintaining scientific literacy, the mental state of scientific literacy, and behaviors of scientifically literate people.

Experiences for Developing and Maintaining Scientific Literacy

Clearly, scientific literacy is an educational goal, and therefore it results, in part, from school experiences. For example, the National Science Education Standards (NRC, 1996) and the Benchmarks for Science Literacy (AAAS, 1993) both describe the content knowledge, skills, and understandings that high school graduates should possess as a result of taking 12 years of science classes. As several of the participants in this study pointed out, one does not have to have a college degree in science to be scientifically literate. In fact, even those with such degrees might be largely scientifically illiterate if "he's just so narrowly focused he sees too small a piece of the picture" (Chemist/science educator).

Not only must one experience a number of years of formal school science, but there are particular types of activities that tend to make, or are necessary to maintain and improve one's scientific literacy. For example, several participants suggested that scientifically literate nonscientists can keep up with some aspect of science through reading, visiting informal education settings (such as museums and zoos), and staying informed on issues involving science by consuming public media. Scientists and science teachers can stay scientifically literate by

'conducting research and taking courses.

Mental State of Scientific Literacy

The "mental state of scientific literacy" refers to a person's knowledge, understandings, skills, motivations, and attitudes about science. We have divided the mental state into four interactive dimensions, including the cognitive, procedural, affective, and volitional dimensions.

Cognitive Dimension. The "Cognitive Dimension" refers to the knowledge and understandings of science necessary for scientific literacy. According to our participants, a scientifically literate person will have some knowledge of the facts, concepts, theories and so forth that arise from one or more disciplines of science (physics, chemistry, biology, earth and space sciences). A scientifically literate person should also have a general understanding of what science is (and what it is not), as well as how it is conducted. In addition, a scientifically literate person should know how science is used in our daily lives and how it influences our society and world.

Procedural Dimension. Knowing something about science is only one part of scientific literacy. A person should also "be able to do" certain things, hence the "Procedural Dimension" is included in our Framework. A scientifically literate person may have skills in several domains, including the cognitive abilities, procedures or processes of science, manipulative (pyschomotor), communication, and information-gathering domains. The cognitive skills include "habits of mind" such as being able to think rationally and logically. Other cognitive abilities of the scientifically literate person include problem-solving and decision-making skills. Scientifically literate people must also be able to learn more science when necessary throughout their lives, because science (and technology) are forever changing and developing.

Science is the process of searching for understanding about our lives and our universe, as well as the information we have gained through this search. Thus, some participants expect a scientifically literate person to be able to actually carry out (simple) scientific tests, i.e., searches for understanding. In order to conduct their tests it will be necessary for a scientifically literate person to be able to manipulate certain equipment, like microscopes. Computer skills are essential for scientific literacy according to some participants. At the very least, scientifically literate people should be able to use computers (along with other media) gain the information they seek concerning some scientific concept or issue they wish to learn about.

Volitional Dimension. A person may have the knowledge and ability to do something, but have no desire to do so. We call the motivation to pursue scientific literacy the "Volitional Dimension" of our Framework. A scientifically literate person must be willing to put their science knowledge and abilities to use in their daily encounters with problems and issues. In addition,

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'they will continue to learn science, as necessity or interest directs, throughout their lives.

Affective Domain. Certainly people would not be motivated to use science simply because they know something about it and can do it. If they are to use it, they should also have an interest or positive attitude towards science. They should have an appreciation for what science does in their lives, and for how science, as a way of knowing and thinking, influences our society. And they should be familiar with the values of science, such as respect for "logic," "evidence," "honesty," "thoroughness," and "truth," and so forth. They should be willing and able to apply these values in making decisions about issues involving science.

Behaviors of Scientifically Literate People

Knowing some science and having the ability to use that knowledge may not be sufficient to qualify someone as scientifically literate. Sometimes our participants imply, if not explicitly contend, that to be considered scientifically literate a person must actually do certain things, i.e., they will display certain behaviors or undertake certain acts. The behaviors already discussed include keeping up with science in the news, visiting museums and other informal science education settings, taking science courses, and actually doing science. One of the most important behaviors of the scientifically literate person is acquiring more information about science after he or she leaves school. Another important behavior is actually taking part in the democratic decision-making process on public issues involving science.

Implications of the Framework

We believe that securing consensus on the meaning of "scientific literacy" is important. It will be difficult to develop scientifically literate people if we do not agree on the interpretation of that term. If one thinks of our framework as a description (not definition) of scientific literacy, then one implication is that there is not as much disagreement about what scientific literacy "means" as some have suggested (Champagne & Lovitts, 1989; Shamos, 1995). When people are questioned about their views on scientific literacy, they tend to emphasize one element in our framework, rather than the whole. In particular, they discuss the "part of the elephant" that is closest to them, as reflected by their occupation, interest, or ideology (Champagne & Lovitts, 1989). In other words, people do not disagree so much as they talk past one another. We believe that a comprehensive framework, such as the one we have presented, can bring these diverse views together and build consensus among all stakeholders in the science education reform process.

No matter how good on paper a plan is for accomplishing scientific literacy, it will only work if teachers can understand it and will buy into it. Teachers can easily refer to our framework and ask themselves, "What else do my students need?" All four dimensions of the mental state of

scientific literacy can be addressed in any science course, and even in any particular lesson sequence. Curriculum developers can look at the Framework and decide whether to include a particular activity or not. The Framework can also be used to guide assessment, although we would certainly have to work hard at devising means of assessing the volitional and affective dimensions.

Thus, a consensual framework would allow educators to design the curricula and provide the instruction necessary to develop the public's scientific literacy, as well as to assess their state of literacy. It might also be helpful in establishing who is responsible for developing the various elements.

Recently, some have suggested that because of the multiplicity of definitions for the term "scientific literacy," the goal should be abandoned (e.g., see Shamos, 1995). We disagree with this conclusion for several reasons. First, widespread usage and long history (Hurd, 1958) of the term "scientific literacy" make it hard to ignore or abandon. Science educators have devoted (and are still devoting) a lot of time, energy, and money into the goal of scientific literacy. Another reason is the term "scientific literacy" has "an intuitive appeal and convincing ring of legitimacy" (Prather, 1990). The "literacy" part of the term is especially recognized by people outside the field of science education, and connotes a socially desirable state. "Literacy" is viewed as a broad and abstract term that is an appropriate goal of education (Eisenhart, Finkel, and Marion, 1996). Bybee (1997, p. 150) says

> The good news is that the broad and abstract nature of the goal--scientific literacy allows widespread agreement and a unifying idea for diverse groups within the science education community. For instance, science teachers, administrators, parents, curriculum developers, teacher educators, scientists, and policy makers can all support the idea of achieving scientific literacy. The bad news is that these diverse groups within the science education community have different perspectives on what scientific literacy is and how to achieve it.

He suggests that while it is true the term's definition has not always been clear, today there is much more agreement than disagreement about what constitutes scientific literacy. Furthermore, he compares scientific literacy with "justice for all," and asks

> When we do not achieve this goal, what is the proper recourse--to change the goal or to refocus our efforts on those aspects of the goal that we are not achieving? I think that we would maintain the goal and reform our efforts. Achieving scientific literacy for all students should remain our purpose while our efforts within the educational community evolve to better achieve that purpose. (Bybee, 1997, p. 209-210)

We certainly agree, and suggest that a framework such as the one we have used here can help

science educators and others interested in scientific literacy to better work towards its realization.

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Appendix A

Appendix B

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